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LIVE QUALIFICATION OF THE LUMBAR PAD AND PULSATING SEAT CUSHION FOR THE S-3A ESCAPE SYSTEM

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A lumbar pad, designed by Lockheed-California Company which can be adjusted vertically, and pulsating seat cushion were proposed for the S-3A aircraft ejection seat in order to assure maximum comfort and alertness.

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This report documents the ejection tower testing of both these items to determine their effect on ejection positioning and dynamic response of the aircrewmen during ejection. Human and dummy ejection tower tests were successfully completed on both items, which were subsequently recommended for use in the S-3A aircraft.

RESULTS

PHASE I - LUMBAR PAD

A human factors study was conducted to determine the proper placement of the lumbar pad. Placement out of the lumbar region of aircrewmen is possible with the support assembly configuration sent to NAVAIRDEVCEN by Lockheed-California Company which could place the mid-axillary line of the spine in an orientation other than parallel to the thrustline. Thus, the pad could be potentially dangerous if adjusted to the full excursion as allowed by the velcro (approximately 8 inches). The results of this study indicated that the lumbar pad could have a safe maximum adjustment of 1 3/4" in the area specified.

The test program was conducted using three live test subjects, starting at 6 g's and increasing in 2 g increments to a maximum of 12 g's. The subjects were 25th, 89th and 92nd percentile in sitting height. At 8 g's, comparison shots were made ejecting all three subjects with and without the lumbar pad. No noticeable difference was observed from the film analysis. The subjects, however, indicated that the seat was more comfortable when it contained the lumbar pad. All ejections up to and including 10 g acceleration were initiated with the D-ring (secondary firing handle). A 12 g ejection was made with face curtain initiation to assure correct positioning, and proved to be successful. This minimal program showed acceptability of the lumbar pad as modified to the allowable adjustment of 1 3/4".

PHASE II - PULSATING SEAT CUSHION

Ejection tests were conducted at 10, 12, and 14 g acceleration levels with both 5th and 95th percentile dummies by weight. They both received two shots at each acceleration level, one in which pulsation was synchronized to occur during ejection and one without pulsation. A delta g was calculated by determining the difference between the reading of the accelerometer in the dummy's chest cavity and the one on the catapult. This delta g was compared with and without the cushion pulsating at each acceleration level. The dummy tests indicated there was no detectable dynamic overshoot as a result of the pulsating cushion.

Live subject tests were then conducted using two subjects approximating a 5th and 95th percentile by weight. Six, 8 and 10 g acceleration levels were obtained with the cushion pulsating. All subject comments were favorable and the ejections were completely successful and trouble free for both subjects. At the 12 g acceleration level, a comparison was made of ejecting with the cushion pulsating and with the cushion not pulsating. A delta g was established as in the dummy tests and again no significant difference was observed.

ACKNOWLEDGMENT

This Command wishes to express appreciation to the following personnel for their assistance in voluntarily acting as subjects for the ejection tower tests. Without their cooperation, this work could not have been completed:

HM1 John McCoy
MM1 Gene Kear
HM1 Woodward Miller
MM1 Robert Brandt

SUMMARY

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INTRODUCTION

The pulsating seat cushion (seat cushion stimulator) was designed for the purpose of stimulating blood circulation in the buttocks and thigh area of an aircrewman who is required to be in a seated position for extended periods of time. The cushion elevates a person in such a manner as to relieve pressure points in the buttocks area, i.e., relieve pressure points at the coccyx and tuberosities while the person remains in a seated position. It is designed to pulse by the inflation and deflation of a pneumatic bladder on a time cycle, thus alternating the pressure points on the buttocks and thighs of the seated person and stimulating blood flow (1).

Since this pulsating seat cushion is proposed for incorporation into the ejection seat of the S-3A aircraft, it was necessary to determine whether it would, in any way, alter survivability or add risk of injury to the aircrewmen.

Analysis of the functioning of the cushion revealed that the only possible detrimental effect would be to cause the aircrewmen to encounter dynamic overshoot if he were to eject while the cushion was pulsating. In order to test for this effect, two live ejection tests were conducted at each acceleration level, one with and one without the cushion pulsating. The acceleration readings on the subject were then compared. A higher G value with the cushion pulsating would be indicative of dynamic overshoot since both shots were conducted under similar conditions.

During the initial part of the program, it was discovered that a lumbar pad was being used in the S-3A escape system that had not been fully qualified since it had not been live tested (man rated) on the ejection tower. Further investigation revealed that this lumbar pad could be adjusted by the aircrewmen which could result in a potential back injury during ejection. Approval and additional funding were requested and received from Naval Air Systems Command (NAVAIRSYSCOM) (AIR-531) to test this pad in addition to the pulsating cushion. The work effort for both pulsating cushion and lumbar pad were performed under AIRTASK No. W21060000.

A program was established to test the lumbar pad. This consisted of a human factors study to establish allowable pad adjustment that would be safe for the aircrewmen, followed by a minimal live ejection tower test program.

Upon completion, an ejection tower test program was conducted on the pulsating cushion with the seat in its proposed configuration, including the approved lumbar pad. The complete program was conducted as Phase I, lumbar pad, and Phase II, pulsating seat cushion.

PHASE I: LUMBAR PAD

A performance evaluation program was completed 9 July 1973 on the S-3A ejection seat at the NAVAIRDEVCEN ejection tower facility. The ejections were made from 6 to 12 g's in increments of 2 g accelerations to determine if the lumbar pad supplied to the Navy by Lockheed-California Company for the S-3A aircraft was acceptable. The test program consisted of a human factors study to determine the allowable pilot lumbar adjustment and live subject ejections to determine if the pad in the allowable adjustment range in any way affected ejection safety.

The human factors study determined the proper placement of the lumbar pad. Placement out of the lumbar region of aircrewmen is possible with the support assembly configuration sent to NAVAIRDEVCEN by Lockheed-California Company. This could cause the mid-axillary line of the spine to be in an orientation other than parallel to the thrustline. The pad could be potentially dangerous if allowed to be moved the full excursion of the velcro (approximately 8 inches) (Figure 1). Excessive head and neck rotation could occur during ejection of the aircrewmen, spinal injury resulting. Most operational Navy aircraft ejection seats have non-moveable lumbar pads installed in the seat bucket (in systems where the seat bucket moves in relation to the seat back, the lumbar pad has the same excursion as the seat bucket). In order to assure maximum comfort of all aircrewmen, a moveable pad with a safe maximum adjustment of 1 3/4 inches was considered desirable (Figure 2). It is noted, however, that a one position lumbar pad could be used as in other aircraft to accommodate all aircrewmen but will result in a sacrifice in comfort. The determination of the pad adjustment and proper placement was made by finding the lumbar region on a number of subjects and marking the spot where the bottom of the lumbar pad fell. The top of the lumbar region can be easily determined by locating the lowest point of the bottom rib and following this point around to the back. The top of the lumbar pad was placed at this point which was found to vary 1 3/4 inches between the percentile extremes in sitting position. The lumbar pad filled and supported the lumbar region adequately and is considered acceptable both from geometric and comfort standpoints.

The in-service acceleration trace of the S-3A escape system was reproduced on a NAMC 40 inch stroke catapult with a special venting technique. This configuration, in conjunction with MK-1 MODO cartridges at various propellant weights, reproduced the trace of 15 g's at a maximum onset acceleration rate of 250 g/sec as obtained on the McDonnell Douglas modified rocket catapult. Catapult pressure and acceleration were recorded on a time based oscillograph record. Three cameras were used in each test: a 1,000 frames per second Photosonics stationary camera, a 400 frames per second Milliken pan and 400 frames per second stationary side camera.

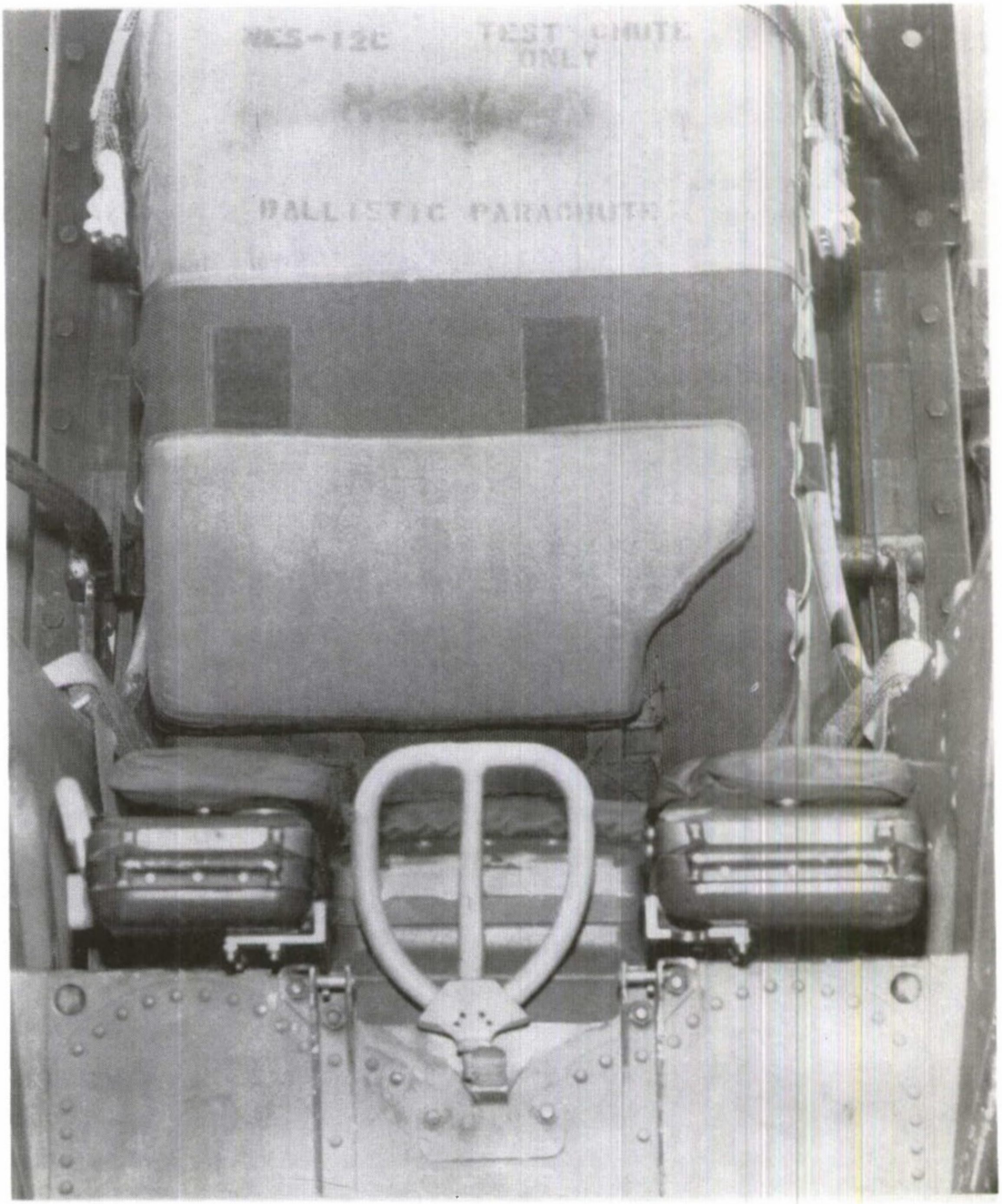


Figure 1. Lumbar Pad Velcro.

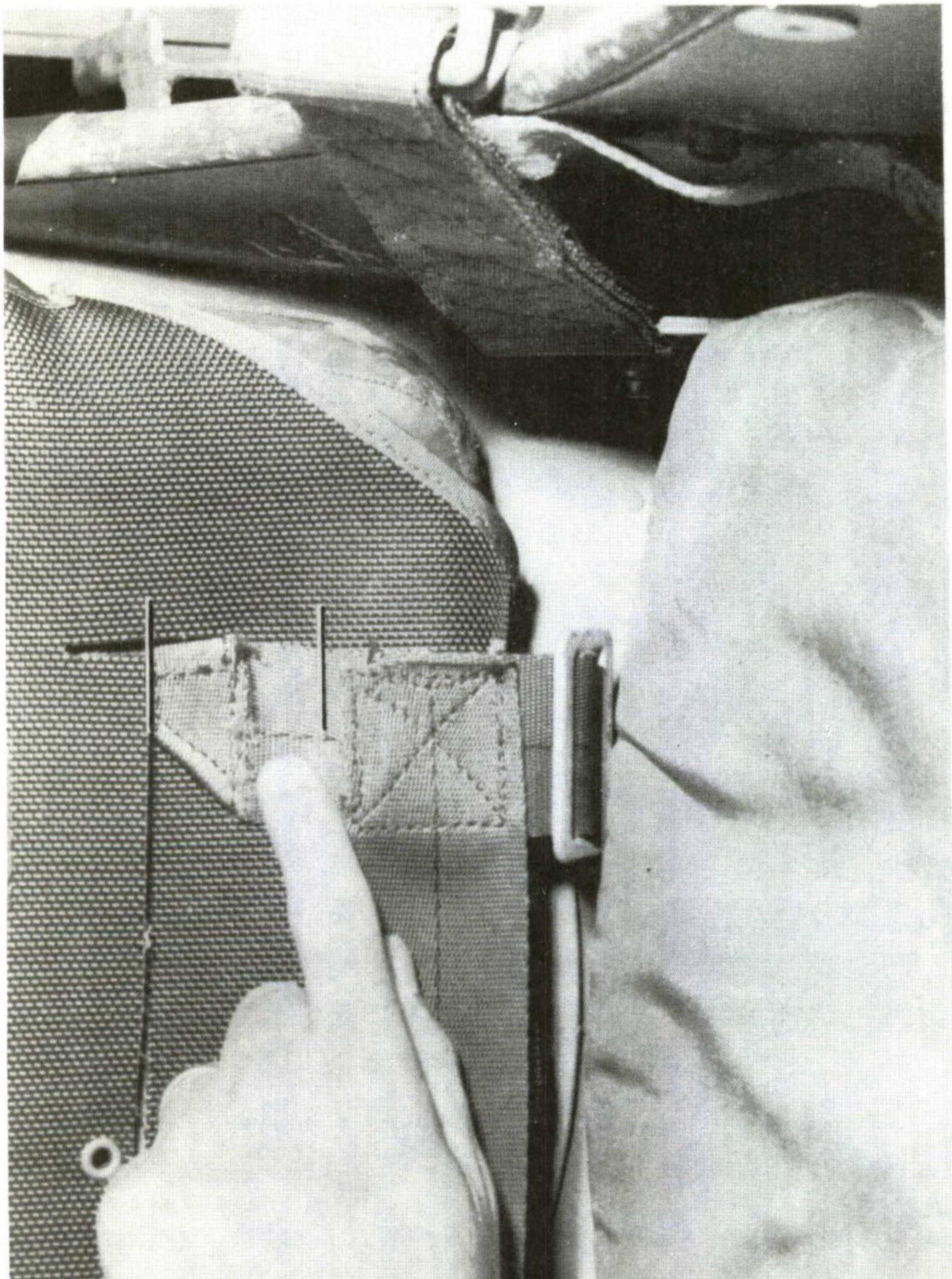


Figure 2. Lumbar Pad Adjustment.

Three subjects were used for the test of the lumbar pad: a 25th percentile subject by sitting height, an 89th percentile subject sitting height, and a 92nd percentile sitting height. At the 8 g acceleration level, comparison shots were made with all three subjects ejected, with and without the lumbar pad. No significant difference was observed from the film analysis of these tests. All ejections up to and including 10 g's were initiated with the D-ring (secondary firing handle). This method of actuation was used because definite head and neck rotation would be present if the spinal alignment was not correct. That is, if the mid-axillary line of the spine was displaced (not parallel to the thrust line) due to the lumbar pad, then body compression resulting from ejection forces would tend to rotate the head and neck into the direction of the misalignment. This movement could be visually observed in the film coverage from the side-mounted camera as a grid board was mounted in the background (Figure 3). At the 10 g acceleration level the subjects still showed no substantial head and neck rotation, thus indicating excellent spinal alignment with the lumbar pad in its proper location. A 12 g ejection was made with the face curtain to assure correct positioning. The results from this shot concurred with the previous test. For this test program, 12 g's were considered sufficient to demonstrate acceptability of the lumbar pad.

PHASE II PULSATING SEAT CUSHION

On 5 September 1973, dummy and human ejection tests were completed on the pulsating seat cushion. The tests were conducted on the NAVAIRDEVCEN ejection seat tower facility. The purpose of this program was to determine if the pulsating cushion would have any detrimental effect on the ejection of an aircrewman. Since the initial installation of the pulsating cushion is intended for the S-3A aircraft, all tests were conducted using the S-3A ESCAPAC 1-E1 escape system. Also, the in-service acceleration history was reproduced.

In establishing the program requirements, all possible problem areas that could be encountered with a pulsating cushion as it pertains to ejection were considered. The principal areas were ejection with cushion deflated, fully inflated, or pulsating. Possible problems that were considered were change in body or spinal alignment due to the cushion or excessive dynamic overshoot on the aircrewman. Dynamic overshoot is encountered when a seat cushion is compressed at first motion of the seat, which causes the aircrewman to lag the seat velocity. He must then "catch up" to the seat velocity, therefore encountering a higher acceleration. This problem was minimized by the Rigid Seat Survival Kit (RSSK) including a very thin comfort cushion. It was determined that the pulsating cushion would not affect body position or spinal alignment while either deflated, fully inflated, or pulsating, since it does not change the relationship of the spine to the seat back and does not raise the buttocks off the seat pan. The cushion in its deflated condition could

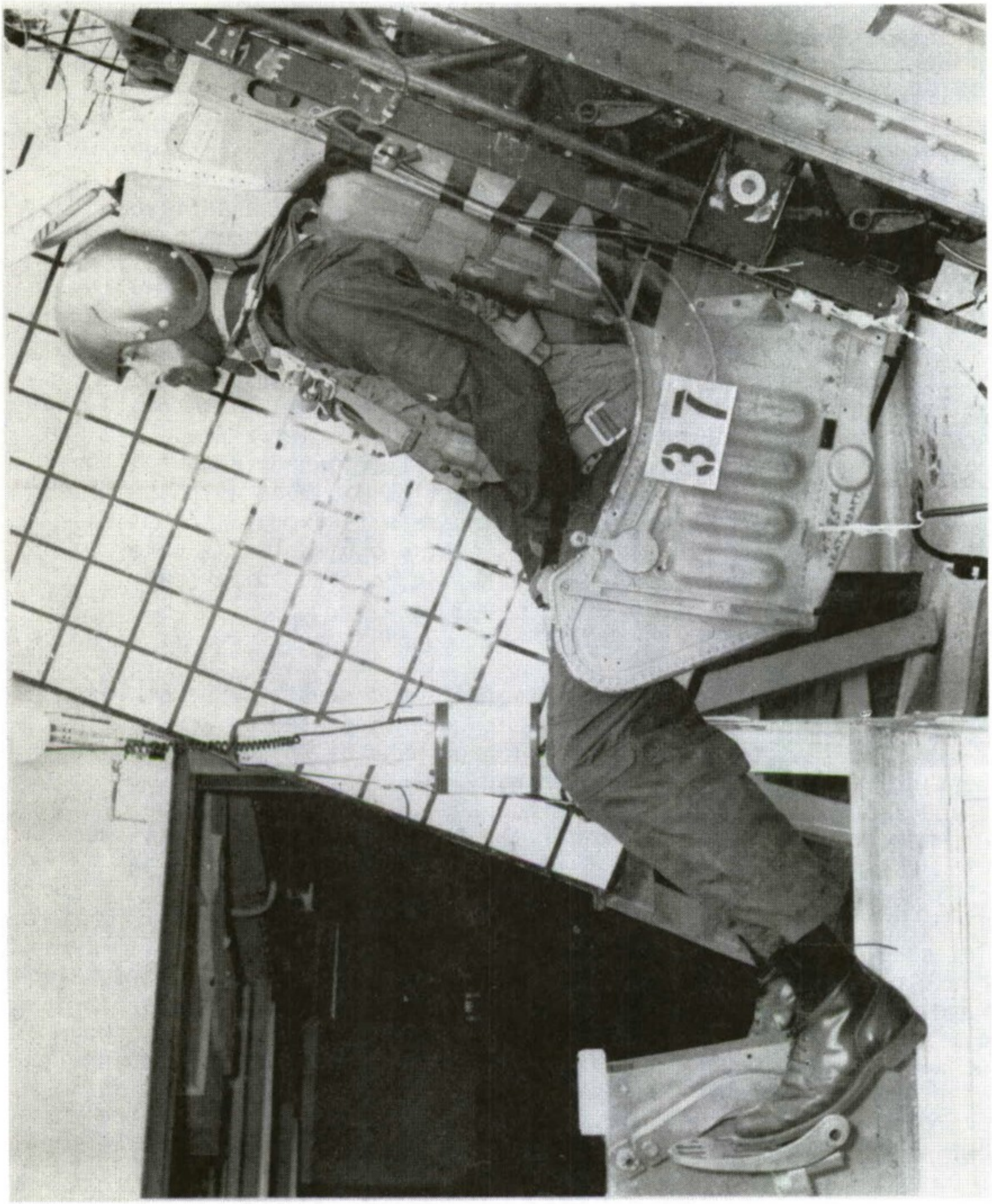


Figure 3. Side View Picture of 95th Percentile Subject.

not affect the acceleration on the man because of its thin construction and material, and thus will not add dynamic overshoot to the system. However, if in the fully inflated or pulsating condition during ejection, the possibility existed for increasing dynamic overshoot. The condition of full inflation is highly improbable since the cushion will never be fully inflated but only partially while pulsating due to its design. In order to verify this analysis, tests were conducted in which cushion pulsation was synchronized with ejection and compared to ejection without pulsation for the purpose of measuring possible differences in the recorded acceleration forces (G). This difference, if any, would be the total dynamic overshoot caused by the cushion (Figure 4).

The set-up adapted specifically for this test included the electrical part of the pulsating mechanism and the air supply which were not attached to the seat. Also included was the pulsating cushion on the seat with appropriate pneumatic line and Wiggins valve quick disconnect to separate the pulsating cushion from its air supply upon first motion following ejection (Figure 5). A pressure transducer was placed in the pneumatic line above the seat portion of the Wiggins valve for the purpose of determining how rapidly the pressure in the cushion decayed to zero following first motion of the seat. Both an accelerometer and pressure transducer were mounted on the catapult. Also, an accelerometer was mounted in the chest cavity of the dummy and one was attached to the human subjects for the live tests. All instrumentation was recorded on a time base oscillograph and the pressure output of the pulsating cushion was directly comparable to all acceleration and pressure readings (by time and magnitude). Photo coverage included two 400 frames per second Milliken cameras, one pan and one side view, and a 24 frames per second front view camera covering the pulsating of the cushion. The in-service acceleration trace of the S-3A catapult portion of the system was reproduced with the same configuration used in the lumbar pad test.

In order to synchronize pulsation of the cushion with ejection, the timing sequence of the solenoid at the specified setting had to be determined. When the solenoid opens to allow air to go to the cushion, a click can be heard. The clicks occur at 12 second intervals and filling of the cushion has a three second duration. For all tests in which pulsation was required, this timing interval was used in order to synchronize pulsation with ejection. The dummy tests were conducted at 10, 12 and 14 G acceleration, with both 5th and 95th percentile dummies by weight. Both dummies received two shots at each acceleration level, one with cushion pulsating and one without. A delta G was calculated by determining the difference between the accelerometer in the dummy's chest cavity and the one on the catapult. This delta G was compared for the shots with and without the cushion pulsating at each acceleration level. The dummy tests revealed no detectable dynamic overshoot due to the pulsations of the cushion.

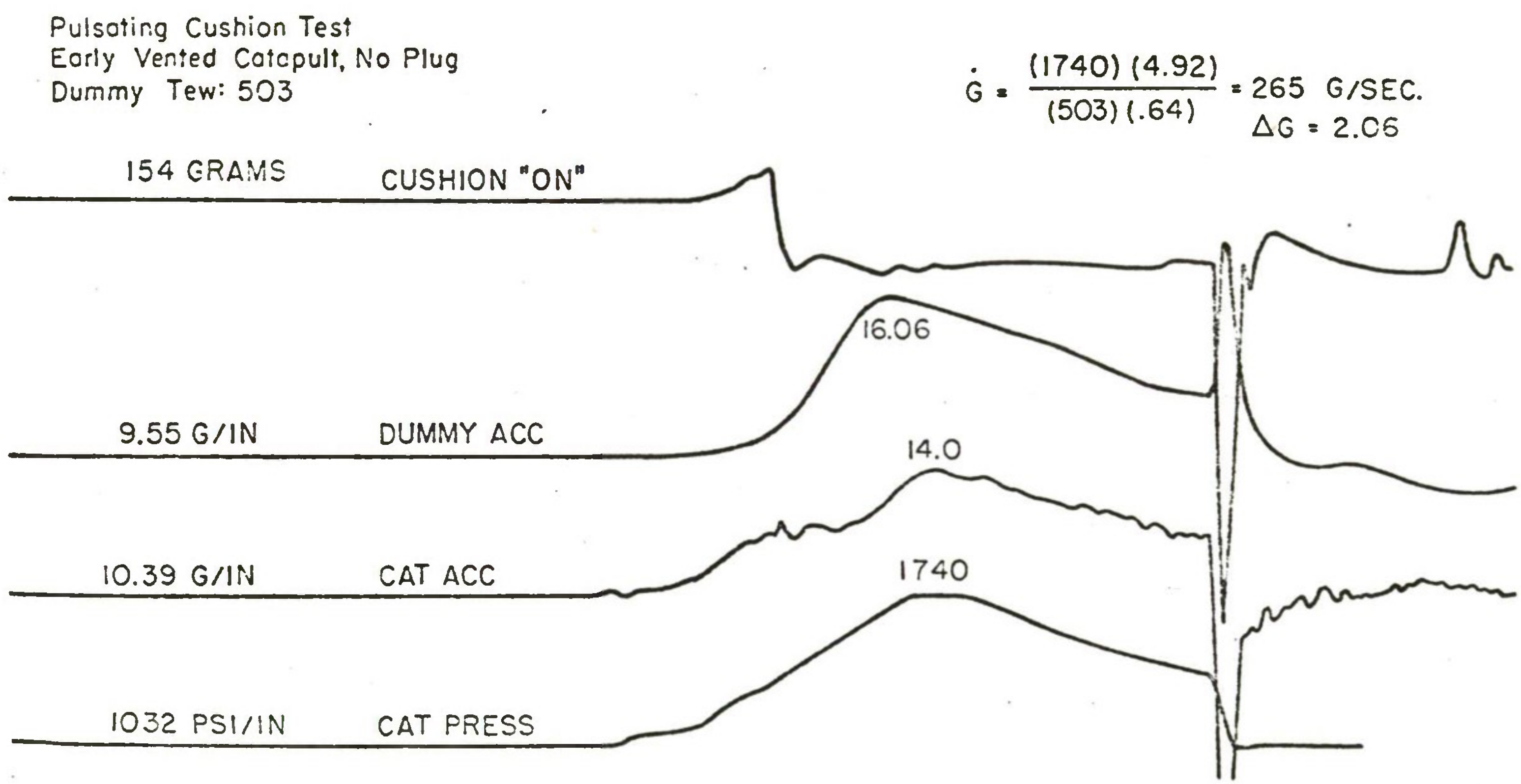


Figure 4. Acceleration Trace of 95th Percentile Subject.

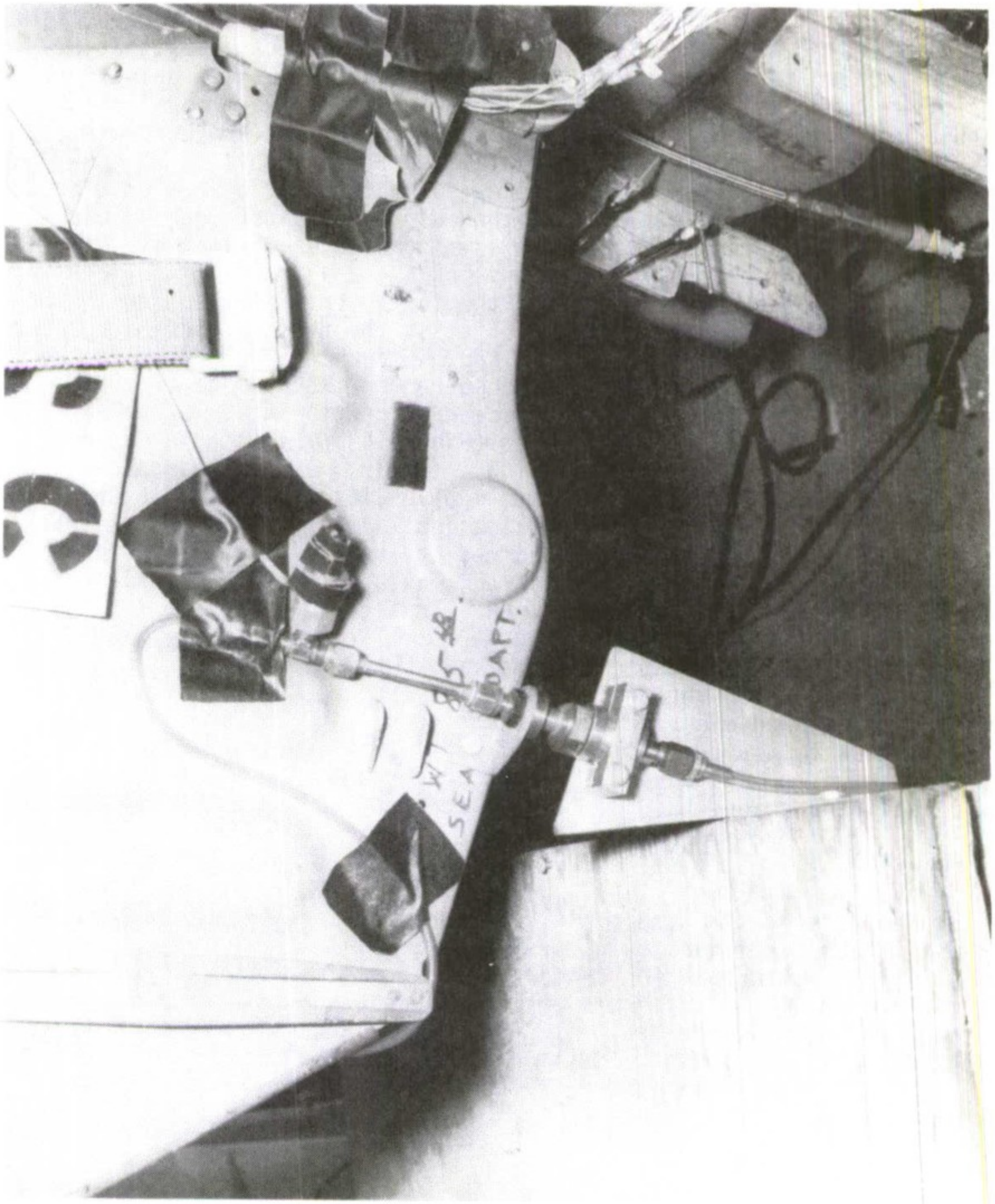


Figure 5. Wiggins Valve in Test Setup.

Human tests were then conducted using two subjects, a 5th percentile by weight subject, and a 95th percentile by weight subject. Tests at 6, 8 and 10 G acceleration levels were conducted with the cushion pulsating. All post test comments were favorable and the ejections were considered safe and acceptable for both subjects. At the lower acceleration level, full flight gear was used (LPA-2, SV-2) to insure compatibility of survival equipment, seat, cushion and aircrewmen. At the 12 G acceleration level, comparison shots were made with the cushion pulsating during ejection and without pulsation to determine any increase in dynamic overshoot. A delta G was established as in the dummy tests and again no significant differences were observed. Analysis of the instrumentation records showed that for both 5th and 95th percentile subjects, the pressure in the cushion had decayed to zero before maximum seat and man accelerations were reached. Complete decay of the cushion pressure occurred on the average of .035 seconds after first motion, while the acceleration peak never occurred less than .070 second after first motion (Figure 4). Had the pulsating cushion been thicker before and/or during inflation, a longer pressure decay time would have occurred which could have caused dynamic overshoot. However, this was not the case for this design. A difference in the shape of the cushion air pressure curves occurred between large and small aircrewmen. The one for the large aircrewmen peaked before decay while no peak occurred with the lighter aircrewmen. This could be attributed to the fact that more air in the cushion under the large aircrewman was forced upon disconnect back through the Wiggins valve where the pressure transducer was located due to the increased weight (Figure 4). This caused no detrimental effect and did not increase the decay time for the air in the cushion. It was felt upon conclusion of these tests that the aircrewmen should not experience any adverse effects or encounter any injuries due to the pulsating cushion throughout the G spectrum of the escape system.

CONCLUSIONS

Acceptability of the lumbar pad, with proper range of adjustment, was proven with the minimum qualifying test program. All three subjects preferred using the lumbar pad for comfort. The human factors study revealed that a maximum of 1 3/4" of excursion is allowable and will accommodate the lumbar region of aircrewmen from 3rd to 98th percentile by sitting height. With this adjustment limitation, the system showed no degradation during live ejections and is therefore considered acceptable both from a safety and comfort aspect.

The proper placement of the pad in the S-3A ejection seat can be determined by placing a ruler on the top of the lumbar pad support assembly, and measuring down 3 5/16". This is where the top of the pad should be at the upper maximum adjustment. The top of the pad at the bottom adjustment should be 5 1/16" below the top of the support assembly. A permanent fix, which is recommended to prevent the lumbar pad from being moved out of the safe adjustment range, can be seen in Appendix A.

The pulsating seat cushion adds comfort to the S-3A escape system and does not deteriorate ejection safety. It is live qualified and therefore recommended for placement in the S-3A aircraft as an integral part of the ESCAPAC 1-E1 escape system.

RECOMMENDATIONS

Although the lumbar pad tested herein is acceptable, an adjustable pad of this type is not the best method for lumbar support. Determining the best possible location for a lumbar pad in the allowable adjustment range is not easily determined by the aircrewmen. For best possible safety and comfort, placement of the pad should be made by a qualified person (flight surgeon, qualified engineer or technician). This can become very difficult in service when qualified personnel always may not be available.

A lumbar pad gives support in order that the kidneys, other internal organs and muscles associated with the lumbar region are not unnecessarily fatigued during long durations of sitting in an ejection seat (1 hour or more). All Navy ejection seats do not have lumbar pads, although all should. For those seat systems that do have lumbar pads, most are not adjustable for pilot percentile variations (i.e., Martin Baker Systems). The location of the lumbar region varies from 3rd to 98th percentile, requiring for maximum effectiveness a lumbar pad with enough excursion to accommodate this range. Although the lumbar pad in the S-3A has enough excursion to accommodate the 3rd through 98th percentile aircrewmen, it is not the best method of lumbar support and comfort as noted above.

Therefore, it is recommended that a study be undertaken to develop a universal lumbar pad that is an integral part of the aircrew members personal equipment. This pad should be fitted initially to each individual aircrew member by his flight surgeon and could be permanently affixed to his MA-2 harness. It should be made universal for all escape systems in Navy aircraft.

It is also recommended that the pulsating cushion be considered for placement in all Navy aircraft to increase the aircrewmens' comfort and alertness. Caution must be taken if a pulsating cushion other than the one tested herein is used. Each different cushion would require complete re-qualification from a physiological, engineering, and safety standpoint.

REFERENCE

1. Koch, H. Aircraft Seat Cushion Stimulator - Unsolicited Proposal to Air Force Systems Command. H. Koch and Sons, Corte Madera, Calif.

APPENDIX A

S-3A Escape System

1. It was determined through a test program that the lumbar pad for the S-3A escape system should be limited to a maximum adjustment of 1 3/4" in order that it will not compromise the safety of the escape system. In describing the modification of the lumbar pad for this adjustment, two parts will be referred to: a lumbar pad and lumbar pad support assembly.

2. With the pad adjusted at the uppermost position, the location of the top of the pad should be 3 5/16" below the top of the support assembly. A line should be drawn across the lumbar pad support assembly at this upper adjustment position (parallel to the top). The top of the lumbar pad should not be placed above this line as it could compromise ejection safety. A warning to this effect should be noted on the support assembly and appear in the NATOPS manual.

3. Measure 5 1/16" below the top of the support assembly (see drawings) and draw another line. This line locates the top of the pad at the bottom adjustment position.

4. The following instructions should be followed to obtain the proper adjustment range of 1 3/4" as specified in paragraph 1.

LUMBAR PAD SUPPORT ASSEMBLY

a. Remove velcro from Support Assembly and mark location.

b. Draw a reference line along the vertical centerline of the right velcro strip axes located on the support assembly. Measure 7 3/8" to the left and draw a second reference line parallel to the first. The second line will not necessarily fall on the centerline where the left velcro strip was located.

c. Place a piece of nylon webbing, 4" long by 2" wide (MIL-W-4088F, Type XVI) on each side 1 1/2" from the top of the support assembly and centered on the reference lines. Draw reference lines in center of webbing as extensions of those in paragraph b.

d. Attach three pairs of male snaps (MS-27980-6N, MS-27980-8N) on these reference lines as specified below.

(1) The centerpoints of the top pair of snaps are located 2 5/16" below the top of the support assembly along the reference lines.

(2) The centerpoints for the second pair of snaps are located 3 3/16" below the top of the support assembly along the reference lines.

(3) The centerpoints for the third pair of snaps are located 4 1/16" below the top of the support assembly along the reference lines.

e. Measure 3 11/16" to the left from the reference line in paragraph b. This is the midpoint of the two reference lines of (b). Measure 8" from the top of the support assembly along this centerline and mark this point. Sew on a 2" square of velcro with the top edge at this mark and centered on the centerline. Refer to drawing #1.

LUMBAR PAD

a. Remove velcro from lumbar pad.

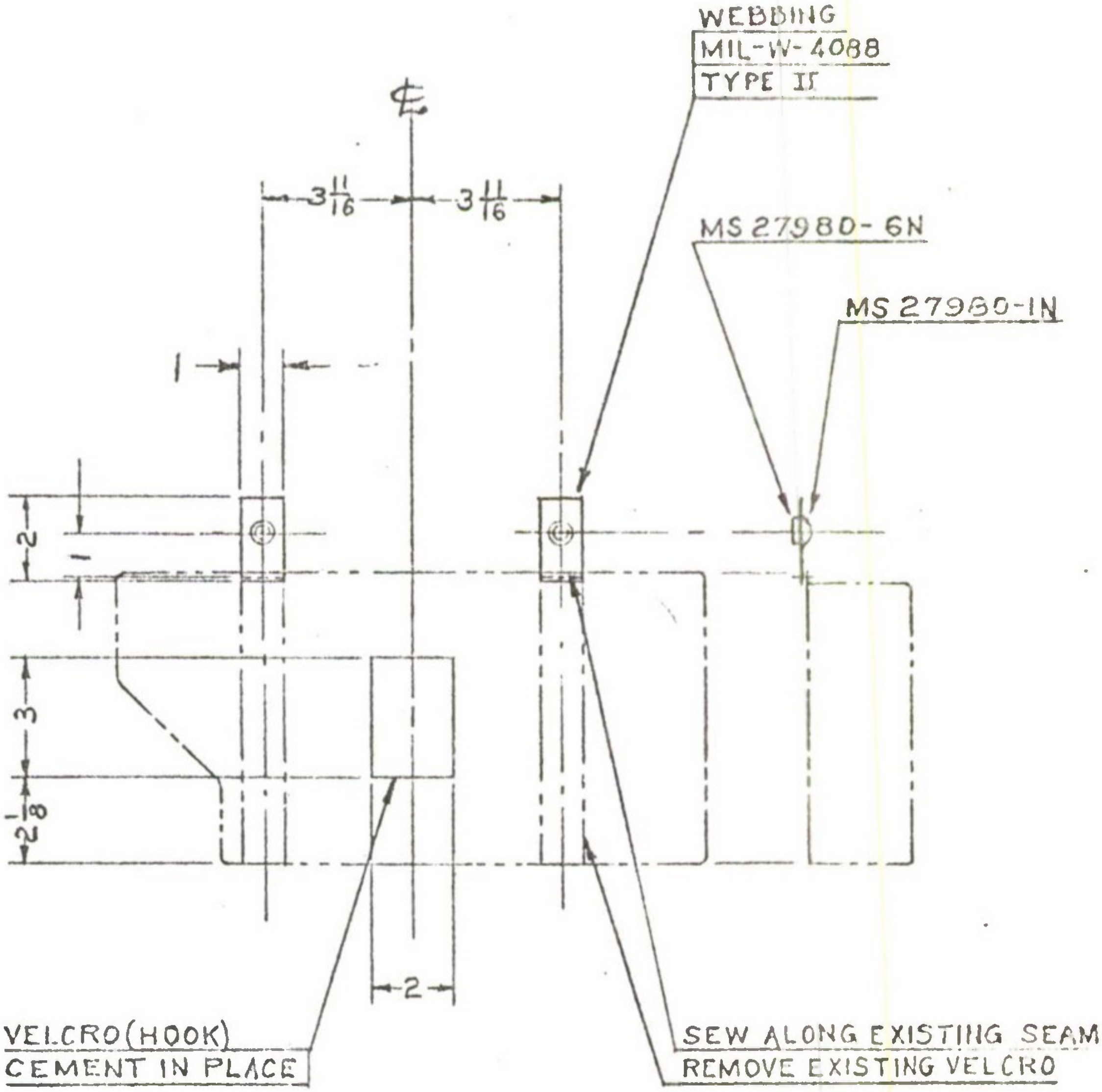
b. Locate centerline of pad along top edge and mark.

c. Glue one piece of velcro 3" long by 2" wide along centerline and centered right to left, with the bottom edge 2 1/8" from the bottom of the pad.

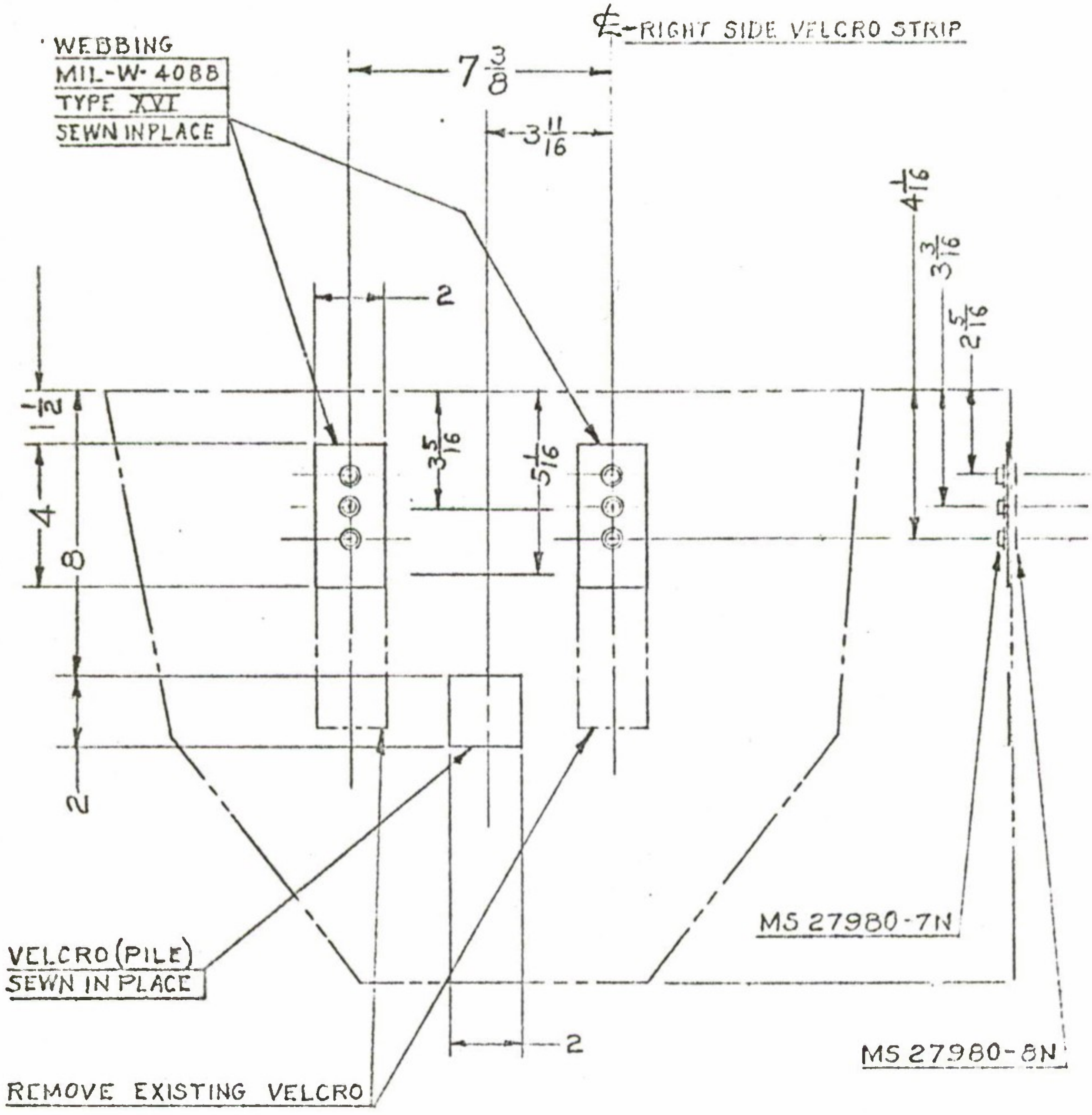
d. Measure 3 11/16" from the centerline in each direction along the top edge of the lumbar pad and mark. This is not necessarily the centerline of the location of where velcro strips were located.

e. Machine sew 2" tabs (Nylon webbing MIL-W-4088, Type II) on each side, on the top edge of the lumbar pad and centered on the specified marks. Sew along the existing seam of the pad. These tabs should contain female snaps (MS-27980-1N, MS-27980-7N) of a type that will mate with the snaps on the lumbar pad support assembly. These are nickel plated snap fasteners, Type II, Size I.

f. The centerpoint of these snaps must be located 1" from where the tabs are stitched to the lumbar pad.



LUMBAR PAD
REAR VIEW



LUMBAR PAD SUPPORT ASSEMBLY

FRONT VIEW